Long Range Detection and Modeling of Sounding Rocket Launches

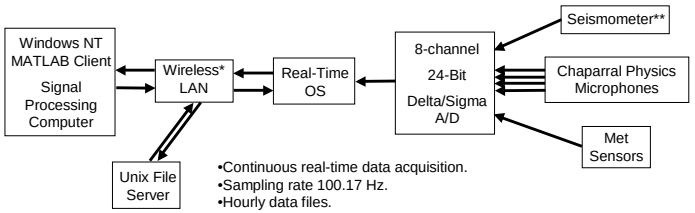
J. M. Noble and S.M. Tenney
U.S. Army Research Laboratory
Adelphi, MD, USA

Abstract

The Army Research Laboratory has been running an infrasonic array at its Blossom Point Research Facility since the summer of 1998. The infrasonic array monitors events in the 3 - 8 Hz window 24 hours a day/7 days a week. Interesting events are tracked down to determine the source of the infrasonic energy. This paper will discuss a series of detections that were determined to be sounding rocket launches from Wallops Island, Virginia. The paper will also discuss acoustic modeling efforts to determine reasons the launches were not always detected.

Description of the Array

The arrays are comprised of 4-5 Chaparral Physics Model 2 microphones spaced at 20-m intervals providing a frequency range of 3-8 Hz. At the center of each array is a small meteorological mast containing a temperature sensor and a Vaisala 425 Ultrasonic Wind Sensor. The site 1 array also has a three axis seismometer to monitor for correlations between the acoustic and seismic signals. The arrays run 24/7 collecting acoustic, seismic, and meteorological data into hourly time blocks. At the end of each hour, a MATLAB based quick-look algorithm runs to provide a graphical display of the data over the hour.



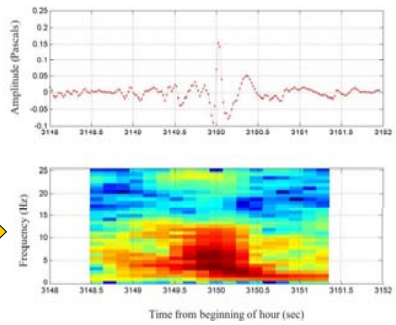
•Continuous real-time data acquisition.
•Sampling rate 100.17 Hz.
•Hourly data files.
*Used only for Array 2
**Only at Array 1

Summary and Future Work

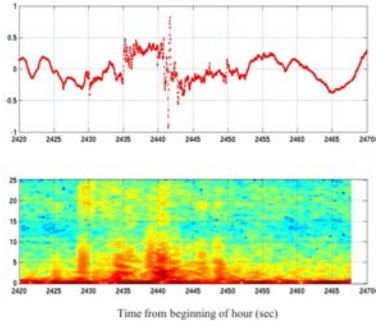
- Infrasound allows for the long range detection of sounding rockets. This is very important since sounding rockets are relatively small rockets.
- Due to the long propagation ranges, the vertical extent of the atmospheric profile of temperature, wind speed, and wind direction must also be high.
- The sound speed profile studied to date show a high altitude wave guide around 15 km. This allows trapping of sound energy from the rocket.
- The characteristics of the wave guide also cause areas of localized shadow zones. The slope in the sound speed profile will determine where these localized shadow zones will exist.
- Additional measurements are planned from sounding rocket launches at closer ranges in order to compare the spectral characteristics of different sounding rockets and determine how those characteristics are being modified by atmospheric propagation.

Characteristics of Sounding Rocket Launches

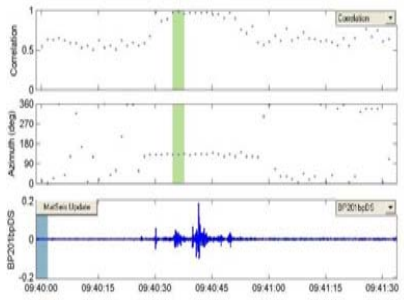
Sounding rockets are relatively small rockets used to carry payloads up to 1500 lbs to altitudes of 1400 km. The diameter of a sounding rocket is less than a meter with a length ranging from 5 – 20 m and may have up to 4 stages. Due to their size and speed, it was not expected to detect launches from our measurement site due to the range (153km). The first suspicion of sounding rocket detection occurred in the spring 2002. A short term event was detected that pointed in the direction of Wallops Island and matched with a sounding rocket launch. After reviewing all of the sounding rocket launches during the operation of the arrays, it was discovered the arrays were detecting the launches a little better than 50% of the time. For 2003, the site 2 array has achieved an 80% detection rate for documented sounding rocket launches.



Time series and spectrogram of a sounding rocket launch. Note the duration of the signal is less than 2 seconds with a frequency maximum of about 5 Hz.



Time series and spectrogram of a multistage sounding rocket launch. Note the duration of the signal is less than 30 seconds with a frequency maximum of about 2 Hz.



Analysis of the Black Brant XI launch on June 2, 2003. Note the high correlation between the channels and strong bearing for 30 seconds.

Propagation Modeling for Sounding Rocket Launches

Infrasound provides a challenge for propagation studies. Due to the long propagation ranges, the vertical atmospheric profile required to make a calculation can be very high. For long range propagation in the atmosphere, there are two naturally occurring wave guides known as the stratospheric and thermospheric wave guides. For the sounding rocket study, balloon data from Wallops Island is being used. The sound speed profile is calculated along the direction of propagation. For sound speed profiles studied to date, a wave guide has been present at about 15 km. This will trap the sound energy from the rocket allowing for long range propagation. The lower half of the wave guide causes the sound to be refracted up from the ground forming local shadow zones, regions where direct or reflected propagation of sound cannot reach, with range. Since the profiles have been similar for detected and undetected launches, then the slope of the sound speed profile in each half of the wave guide is causing the localized shadow zone to move. Calculations of sound loss are being made using ARL's Acoustic Battlefield Aid (ABFA) and BBN's Infrasonic Modeling of Atmospheric Propagation (InfraMAP).